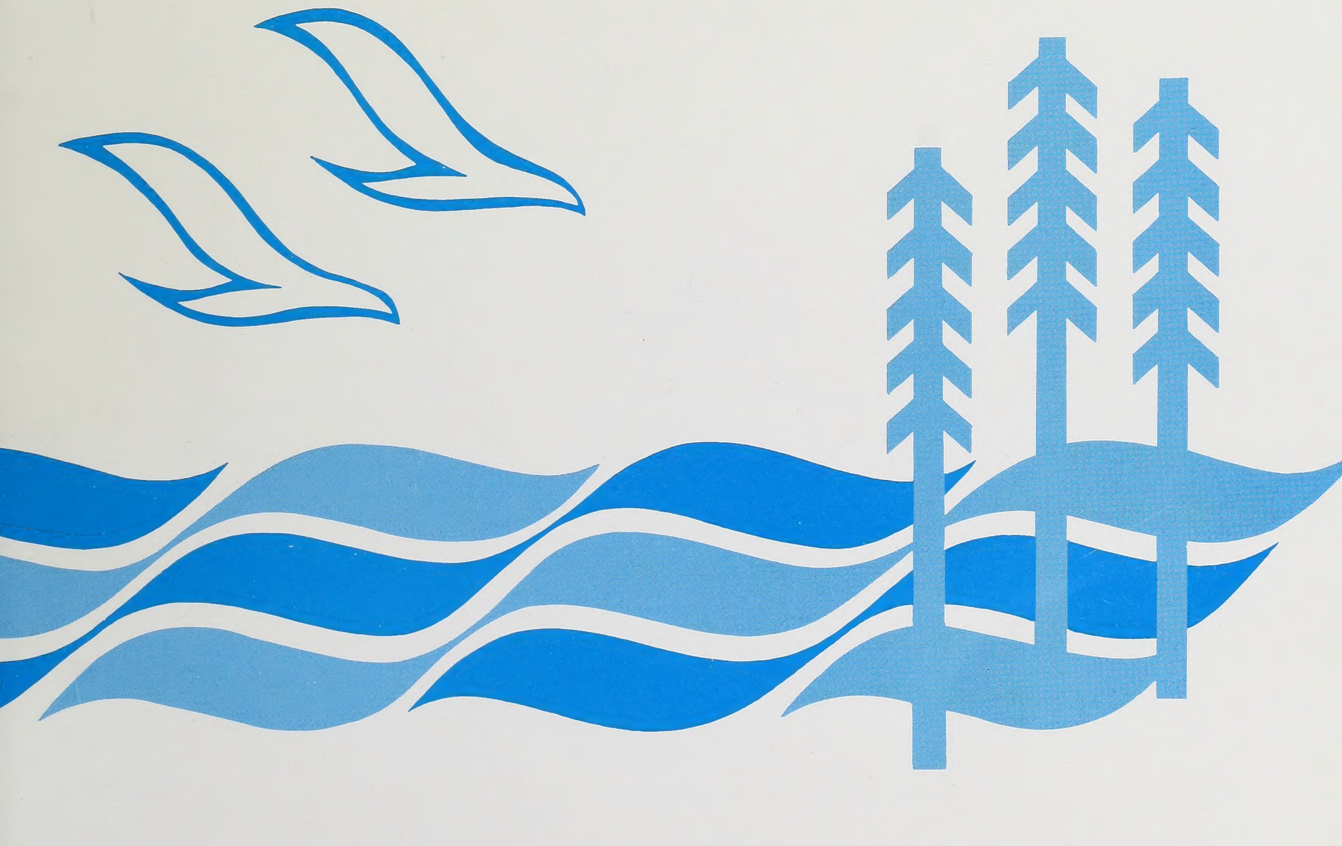
North Saskatchewan River
Characterization of Water Quality in the Vicinity of Edmonton (1982-83) Overview



Alberta

ENVIRONMENT
Environmental Protection Services
Pollution Control Division
Water Quality Control Branch

NORTH SASKATCHEWAN RIVER: CHARACTERIZATION OF WATER QUALITY IN THE VICINITY OF EDMONTON

(1982 - 1983)

OVERVIEW

Prepared by: P.A. Mitchell, M.Sc.
R.S. Anderson, Ph.D.
A.M. Anderson, Ph.D.
A.M. Akena, Ph.D.
J.S. Livingstone, B.Sc.
A. Masuda, B.Sc., P.Eng.
T.B. Reynoldson, Ph.D.
D.O. Trew, B.Sc.
M. Vukadinovic, B.Sc., P.Eng.

Water Quality Control Branch
Pollution Control Division
Environmental Protection Services
Alberta Environment
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INTRODUCTION

The North Saskatchewan River is a major tributary of the Saskatchewan-Nelson river system, which drains a large part of Alberta, Saskatchewan, Manitoba, and the state of North Dakota. From its source, the Saskatchewan Glacier on the Alberta-British Columbia border, the North Saskatchewan River flows eastward across central Alberta and into Saskatchewan where it joins the South Saskatchewan River east of Prince Albert to form the Saskatchewan River. The Saskatchewan River flows into Cedar Lake and then Lake Winnipeg in Manitoba, eventually draining into Hudson Bay through the Nelson River.

Historically, the North Saskatchewan River was an important transportation and communication route, and several early settlements were established along its banks. Many of these settlements have grown into regional population centres, among which Edmonton is the largest. These centres are dependent on the river as a source of water for domestic, agricultural, and industrial purposes, and as the receiving water for various domestic and industrial wastewater effluents. Population growth in the past 50 years has increased agricultural and industrial activities in the North Saskatchewan drainage basin. The river and its valley have also become the focus of many recreational activities and aesthetic interests. More recently, dams have altered the river's flow.

These human activities, as well as climatic variations, resulted in fluctuations in both the quantity and quality of water in the North Saskatchewan River. Public interest in environmental problems has in part led to improved treatment of municipal and industrial waste waters, and water quality in the river has improved greatly since the 1950's. Yet, people generally believe that water quality in the North Saskatchewan River is poor.

In 1982-83, the Water Quality Control Branch, Pollution Control Division, of Alberta Environment undertook a study to update and upgrade water quality data for a 100 kilometre stretch of the North Saskatchewan River from

Devon, upstream of the City of Edmonton, to Pakan bridge, well downstream of impacts within the metropolitan area. The objectives of the study were:

1. To characterize water quality through the study section by assessing bank-to-bank, upstream-downstream and seasonal trends.
2. To compare North Saskatchewan River water quality data with the Alberta Surface Water Quality Objectives.
3. To assess the impact of the city on the river.

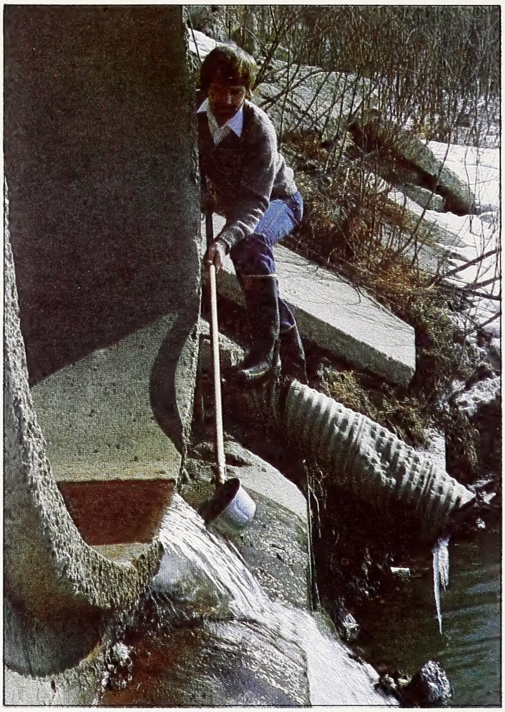
The results of the study are published in a three-volume technical report entitled "North Saskatchewan River: Characterization of Water Quality in the Vicinity of Edmonton (1982-1983)." Part I includes an introduction, an assessment of water chemistry, bacteriology and the quantity of algae growing in the water and on rocks; Part II deals with the zoobenthos, or bottom-dwelling organisms; and Part III is a compendium of data upon which the other two volumes are based. Copies of these three volumes are available from the Water Quality Control Branch, Pollution Control Division, Alberta Environment.

This overview provides a non-technical summary of the study design, major findings and the conclusions presented in the main report.

Water Quality Assessment

The study was designed to answer a number of questions about water quality in the North Saskatchewan River. For example, how do the chemistry and biology of the river vary over the seasons and within the section under study? How does present water quality compare to Alberta Surface Water Quality Objectives? How do urban development and other impacts affect water quality in the river? A final question is, how are uses of the river affected downstream of urban impacts?

The sampling program was not designed to address people's concerns about the quality of their drinking water. Many substances are removed from water when it is treated for drinking, so that the chemistry of the water in



Sampling a storm sewer.

the river is quite different than that which flows from a residential tap. Additionally, most of the impacts discussed in this document occur downstream of water supply intakes. Readers should not confuse river water quality with drinking water quality.

The provincial guidelines called the Alberta Surface Water Quality Objectives were established to protect water for various uses, such as drinking, swimming, agriculture, and propagation of fish and other aquatic life. The establishment of an objective level for a particular substance implies that when this level is exceeded, the use of the water may be impaired or that additional treatment may be needed. These objectives, or other similar published guidelines, aid in assessing water quality in the river.

The impact of urban development was assessed by comparing measured concentrations of constituents to the Alberta Surface Water Quality Objectives, and by comparing water quality at downstream sites with that from upstream sites.

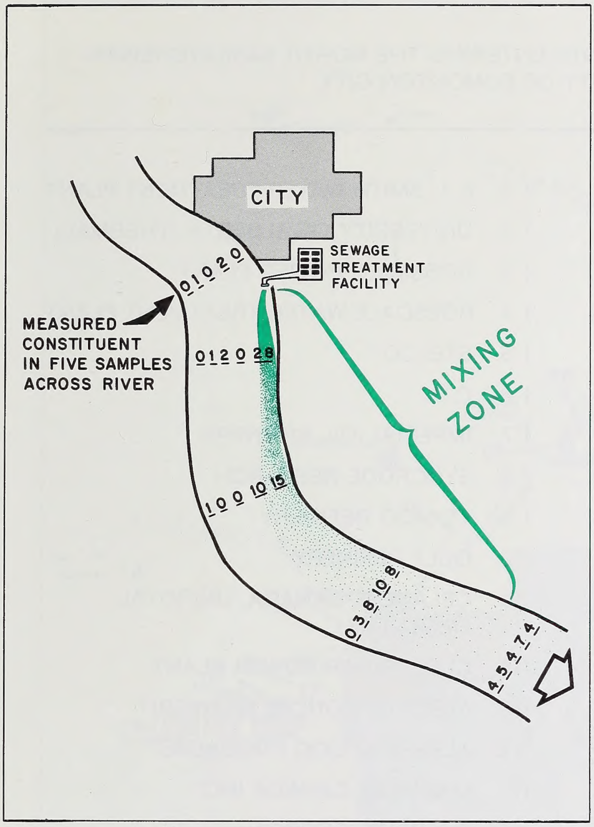


FIGURE 1 Diagram of mixing of an effluent into the river flow. The numbers across the river represent concentrations of a hypothetical substance in five separate samples at each location.

It is generally accepted that the Alberta Surface Water Quality Objectives cannot be applied strictly to water collected immediately downstream of an effluent plume. Thus, the mixing characteristics of the river are also important in assessing water quality. For example, the impact of an effluent may occur only along one bank of the river for many kilometres downstream (see Figure 1). Turbulence and bends in the river gradually mix the effluent into the channel flow. This was taken into consideration during the study by sampling near each bank and in the centre of the river channel. At the most downstream sampling location, Pakan Bridge south of Smoky Lake, the river is considered to be completely mixed most of the time.

Study Design

Three major components of the river ecosystem were identified as requiring study: the water itself, including substances dissolved or suspended in it; the sediments of the river bottom; and the plant and animal life within the water and the sediments. Much of the effort in sampling the river went toward the water component, because it is usually the focus of public concern. In addition to sampling the North Saskatchewan River, point-source contributions to the river were also monitored. These include major tributaries, such as the Redwater River and the Sturgeon River, industrial effluents and municipal sewage treatment plant effluents (Table 1).

Sampling locations on the river were chosen to represent three zones of impact: 1) upstream of the city, considered to be relatively unimpacted, 2) within and immediately downstream of the city, and 3) far enough downstream to show some evidence of "recovery." At each sampling location, samples were collected from the centre of the channel and from sites near the right and left banks (as determined by looking downstream). Figure 2 shows the sampling locations and the locations of major municipal and industrial facilities.

The river was sampled approximately biweekly during each field season. In 1982, samples were collected twelve times between mid-May and early November; in 1983, they were collected ten times between the third week in May and mid-November. Samples were also collected in February and March, 1984.

At each sampling location, water was collected for analysis of chemical constituents such as major ions, metals, and nutrients; organics and biological components such as chlorophyll, which estimates river algae, and indictor bacteria (see listing, Table 2).

Table 1.

MUNICIPAL SEWAGE AND INDUSTRIAL EFFLUENTS ENTERING THE NORTH SASKATCHEWAN RIVER DIRECTLY OR INDIRECTLY IN THE VICINITY OF EDMONTON CITY.

M 1.	THORSBY	I 1.	E. L. SMITH WATER TREATMENT PLANT
M 2.	CALMAR	I 2.	UNIVERSITY OF ALBERTA (THERMAL)
M 3.	DEVON SEWAGE TREATMENT PLANT	I 3.	ROSSDALE POWER PLANT
M 4.	INTERNATIONAL AIRPORT	I 4.	ROSSDALE WATER TREATMENT PLANT
M 5.	LEDUC	I 5.	STELCO
M 6.	NEW SAREPTA	I 6.	C.I.L.
M 7.	BEAUMONT	I 7.	IMPERIAL OIL REFINERY
M 8.	NISKU	I 8.	SYNCRUDE RESEARCH
M 9.	GOLD BAR WASTEWATER TREATMENT PLANT (GBWTP), EDMONTON	I 9.	TEXACO REFINERY
M10.	BREMNER SEWAGE LAGOONS	I10.	GULF REFINERY
M11.	ST. ALBERT SEWAGE LAGOONS	I11.	CELANESE CANADA, UNIROYAL, FIBREGLAS
M12.	ARDROSSAN	I12.	CLOVER BAR POWER PLANT
M13.	FORT SASKATCHEWAN	I13.	ALBERTA CONCRETE, NESBIT
M14.	ONOWAY	I14.	ALBERTA FOOD PRODUCTS
M15.	STONY PLAIN	I15.	MANVILLE CANADA INC.
M16.	PARKLAND VILLAGE	I16.	SHERRITT GORDON
M17.	SPRUCE GROVE	I17.	UNION CARBIDE
M18.	MORINVILLE	I18.	DOW CHEMICAL
M19.	BON ACCORD	I19.	ALBERTA CONCRETE, VILLENEUVE
M20.	GIBBONS	I20.	DIAMOND SHAMROCK
M21.	LEGAL	I21.	SHELL REFINERY, SCOTFORD
M22.	REDWATER	I22.	ESSO CHEMICALS, REDWATER
M23.	TOFIELD		
M24.	CHIPMAN		
M25.	LAMONT		
M26.	BRUDERHEIM		
M27.	THORHILD		
M28.	RADWAY		
M29.	WASKATENAU		

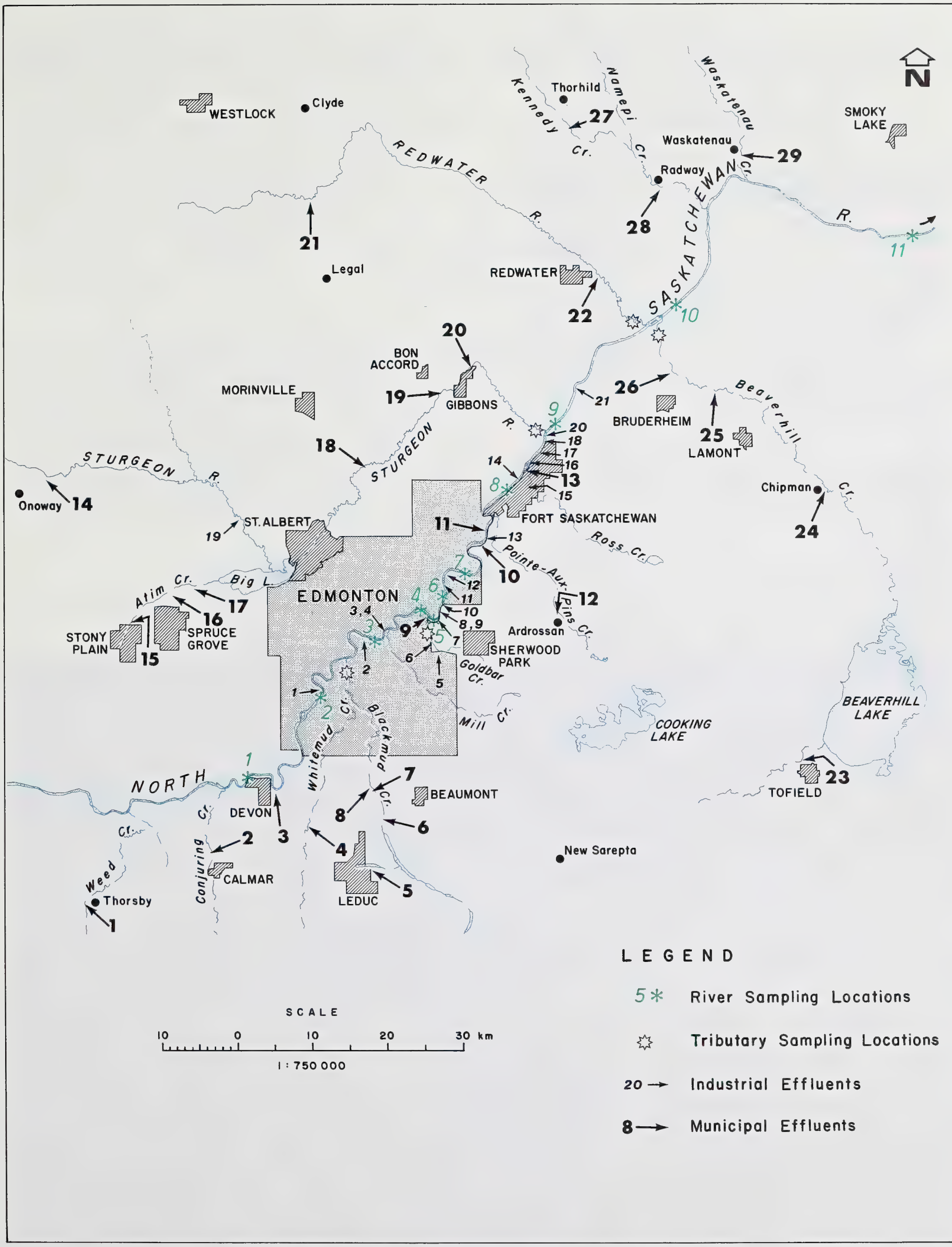


FIGURE 2 Map of North Saskatchewan River in the vicinity of Edmonton showing sampling locations and the municipal and industrial effluents listed in Table 1.

Table 2.

CHEMICAL AND BIOLOGICAL CONSTITUENTS MEASURED IN THE 1982-1983 STUDY, NORTH SASKATCHEWAN RIVER.

FIELD MEASURED CHARACTERISTICS

Temperature
Depth
Flow
Dissolved Oxygen
Conductivity

MAJOR IRONS AND RELATED CONSTITUENTS

pH
Calcium
Magnesium
Hardness
Sodium
Potassium
Chloride
Fluoride
Carbonate
Bicarbonate
Alkalinity
Fluoride
TDS

OXYGEN DEMAND

Biochemical Oxygen Demand
Chemical Oxygen Demand

NUTRIENTS

Phosphorus (total)
Nitrogen (total part.)
Ammonia dissolved
Nitrite
Nitrate-Nitrite
Total Kjeldahl Nitrogen
Silica

METALS

Mercury
Cobalt
Copper
Nickel
Cadmium
Lead
Zinc
Beryllium
Aluminum
Arsenic
Selenium
Chromium
Manganese
Molydenum
Vanadium
Iron

CARBON

Dissolved Inorganic Carbon
Dissolved Organic Carbon
Total Particulate Carbon

RESIDUES

Total Residues
Filterable Residues
Non-filterable Residues

ORGANICS

* Polychlorinated Biphenyls (PCBs)
Phenolic Compounds
Cyanide

* **Priority Pollutant Scan:**

Extractables - 79 compounds
Purgeable - 24 compounds
Chlorinated Pesticides
Chlorinated Herbicides
Organophosphorus Pesticides
Organonitrogen Pesticides

* **SEDIMENTS**

Priority Pollutant Scan
Extractables (79)
Chlorinated Pesticides
Chlorinated Herbicides
PCBs
Metals

BIOLOGICAL CONSTITUENTS

Total Coliform Bacteria
Fecal Coliform Bacteria
Fecal Streptococci
Standard Plate Count
(Heterotrophic Bacteria)
Chlorophyll **a**:
Benthic Algae
Free-floating Algae

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* *one survey only, 5-6 October, 1983*

An extensive program to monitor the zoobenthos, or bottom-dwelling organisms, was undertaken in 1982 to complement the sampling of other constituents. These organisms act as useful indicators of long-term water quality, since many species live two or more years and they are relatively immobile on the river bed. Additionally, many species are very sensitive to pollution, and their presence is considered to be indicative of clean water. The algae that grow on rocks were also sampled for similar reasons.

The sediments on the river bed interact with the water, and may accumulate substances that are undetectable in the water itself. A preliminary survey of the sediments was completed in autumn, 1983. The main purpose of this survey was to provide an initial assessment of sediment chemistry, and to aid in the interpretation of data from the water component.

Potential Sources of Pollution to the River

There is a large and growing percentage of the land base in the Edmonton metropolitan area devoted to urban and industrial development. High concentrations of such development generate effluents from industrial plants, municipal sewage treatment plants, and storm and combined sewers. Industrial and sewage treatment plant effluents are concentrated as point sources. Most discharge continuously throughout the year. Operating under the Clean Water Act, the Standards and Approvals Division of Alberta Environment grants licences which specify discharge limits of these effluents. The Pollution Control Division monitors the discharge for compliance with the licence.

There are approximately 220 storm water and combined storm/sanitary sewer outfalls to the river within the boundaries of the city.

These discharge during periods of snow melt or during rain events. The City of Edmonton and Alberta Environment have conducted preliminary studies on the quality of these effluents. However, their impacts are not well defined, because of the large number of these storm water outfalls, and because their effect on the river is complex.

Potential sources of pollution in the North Saskatchewan River come not only from identifiable point sources, but also from diffuse runoff from lands used for agriculture and from changes to drainage patterns due to diversion and construction. Such non-point sources are difficult to assess, because they are associated with seasonal runoff and storm events, with little input during dry weather.

Other possible sources of contaminants within the city are the eighteen major snow dumps operated by the City of Edmonton during winter. The volume and composition of the meltwater from these dumps varies over time. The city is required by licence to monitor the composition of water from one of the snow dump sites each year.

River Flow and Water Use

Flow on the North Saskatchewan River is regulated by two hydroelectric power dams. The Brazeau Dam, on the main tributary, began operation in 1965; the Bighorn, on the mainstream, was completed in 1972. These dams lower the flood peaks and augment

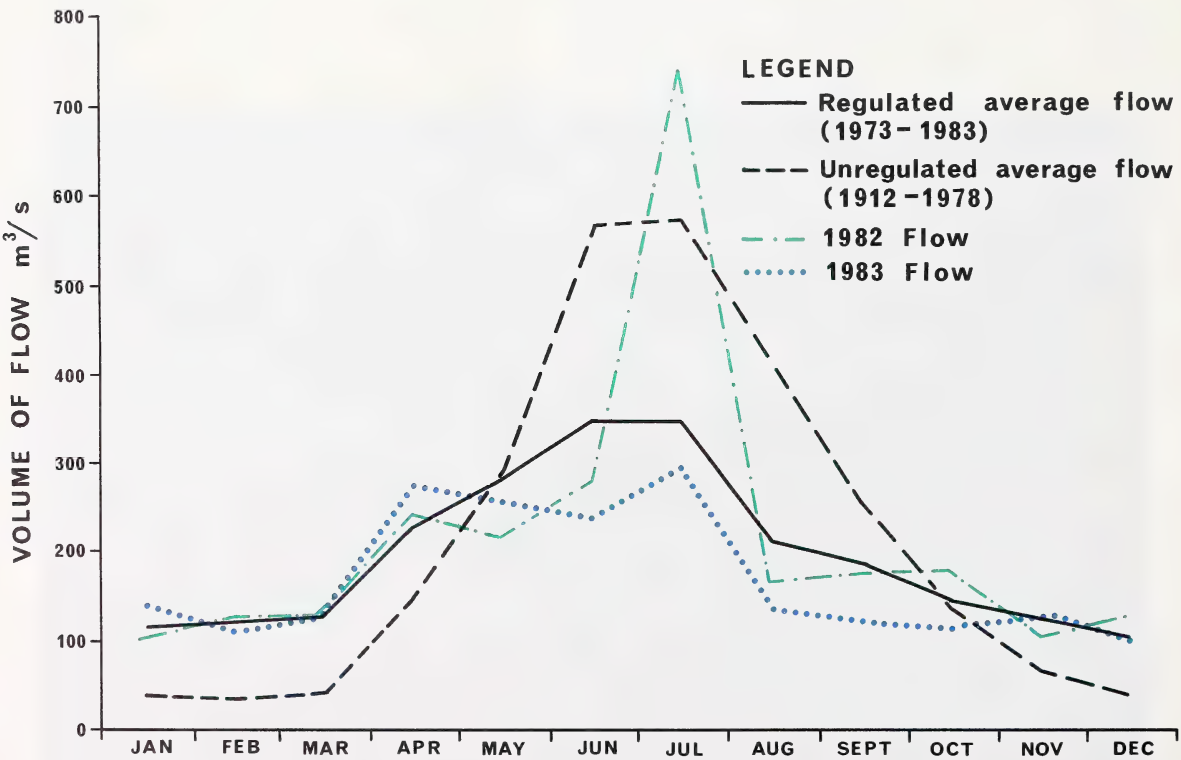


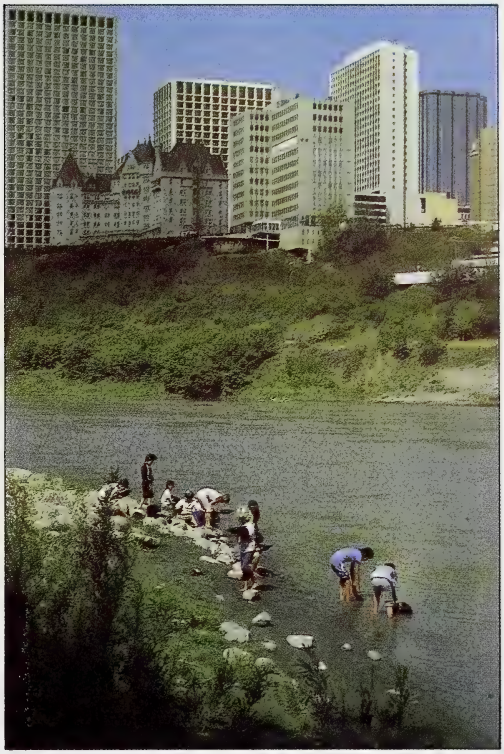
FIGURE 3 **Flow (m^3 per second) in the North Saskatchewan River.**

winter flows.[1] Based on data since 1973, the lowest average monthly flow in the river occurs in December and highest flow occurs in June and July during mountain snowmelt (see Figure 3). During the 1982 study year, flow in July was about twice the historical average for that month; flows during the other months were near or below normal. In 1983, flows were below normal throughout the summer and near average the other months.

Alberta is required by the Prairie Provinces Water Board to supply 50% of the unregulated flow in the North Saskatchewan River to Saskatchewan. The reservoirs are used to ensure that the specified flow is attained.

The largest consumer of North Saskatchewan River water in the study section is the City of Edmonton. This withdrawal is used for municipal supply and for power plant cooling. Most of this water is returned to the river unaltered. The annual net consumption of river water amounts to less than one percent of the annual average flow.

An important use of the river is the assimilation of waste loads. The licence requirements for effluent loads ensure there is sufficient capacity in the river to dilute or safely degrade these wastes. High river flows provide greater dilution, but the loading from non-point or diffuse sources and city storm sewers increases greatly during wet weather.



[1] *Crosby, J. 1982 Prairie Provinces Water Board Water Demand Study: Environmental Considerations in the Saskatchewan-Nelson Basin - Alberta. Planning Division, Alberta Environment.*

RESULTS OF THE STUDY

Temperature

North Saskatchewan River water temperatures in the study section ranged from 0° C in winter to about 25° C in summer. There was less than 1° C difference in water temperature between Devon and Pakan (the furthest upstream and furthest downstream locations in this study). Temperature differences can be somewhat greater where cooling water effluent from power plants enters the river. However, the increases in temperature at these locations were within the Alberta Surface Water Quality Objective of a 3° C rise. This temperature difference probably has a more positive than negative impact, causing open water in winter which enhances aeration.

Dissolved Oxygen

Adequate dissolved oxygen is essential for aquatic life. Oxygen increases in water as a result of turbulence and aeration, and via photosynthesis of plants. It decreases as plants and animals respire, and as organic material is decomposed by bacteria.

In the study section of the North Saskatchewan River, oxygen was near or above saturation[2] most of the year. There were seldom significant differences in site-to-site or bank-to-bank values. The lowest levels, ranging from about 65% to 85% saturation, were noted at two different times of the year - midwinter (February) and midsummer (July). A midwinter decline in oxygen is typical for most rivers, because ice cover prevents reaeration, and the reduced photosynthetic activity of plants cannot offset the effects of respiration. The summer decline is probably a result of plant and animal respiration during darkness, when no oxygen is produced by photosynthesis. At all times during this study, dissolved oxygen complied with the Alberta Surface Water Quality Objective of a minimum of 5 milligrams per litre. There were no apparent direct impacts due to the lower midwinter and summer dissolved oxygen levels.

[2] *When water of a given temperature and pressure holds the maximum possible amount of oxygen or other gas, it is considered saturated with that gas.*

Major Ions

Concentrations of major ions[3] were usually lowest during high-flow periods in the North Saskatchewan River (especially during spring and early summer runoff periods) and highest during low-flow periods (especially in August, but also in midwinter).

The dominant ions in the North Saskatchewan River are calcium and bicarbonate. The pattern of dominance of the eight major ions in the river is typical of many lakes and rivers in central Alberta. This pattern did not change between Devon and Pakan, although the concentration of most ions increased slightly in a downstream direction. Three ions, sodium, chloride and potassium, were significantly higher at Pakan. Municipal sewage discharges were the main source of the higher concentrations of sodium and chloride downstream, with tributary streams and industries contributing lesser amounts. For potassium, the largest contribution came from the tributary streams.

There are no Alberta Surface Water Quality Objectives for most major ions measured in this study. Concentrations of these ions are extremely variable in natural waters, and they are considered harmless even at much higher concentrations than occur naturally in most Alberta surface waters. No impacts are believed attributable to changes in major ion concentration throughout the study of the North Saskatchewan River.

Non-filterable Residues

Non-filterable residues, or suspended solids, are particles of soil or organic debris that would be removed if the water were filtered. Non-filterable residues were generally highest during high-flow periods as a result of erosion or wash-off from the land draining toward the river.

[3] *The eight major ions dissolved in surface waters are Sodium, Potassium, Magnesium, Calcium, Carbonate, Bicarbonate, Chloride and Sulfate.*

The Alberta Surface Water Quality Objective for non-filterable residue is based on a change from background conditions. Therefore, it is difficult to apply to a river in a developed basin because it is not known how much suspended material would have been in the river before it was developed. However, if we assume that conditions at Devon represent "background", 78% of the samples collected during the study complied with the objective. Most exceedences occurred during high runoff periods and seem to have city storm sewers as their principal source.

The main impacts of elevated levels of non-filterable residue would probably be on the plants and animals in the river. Sediment suspended in the water reduces light penetration and, as it settles out, fouls habitats of various organisms.

Metals

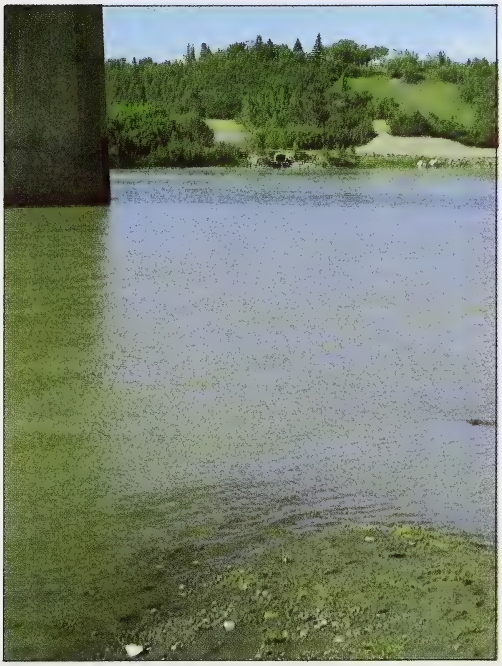
Metals occur naturally in surface waters, but also may derive from industrial effluents and automobile exhausts. Several metals are toxic at high concentrations, but toxicity varies among the forms in which they occur in the environment.

Sixteen metals were analyzed in water samples collected during the study. Of these, mercury, cadmium, selenium, molybdenum, cobalt and beryllium were undetectable in all samples. Four others, copper, chromium, vanadium and arsenic, occurred consistently at low levels during the study and showed little change between upstream and downstream sites. Iron and aluminum increased only when flow in the river was high, indicating an association with suspended solids and runoff.

Only four metals showed increased concentrations downstream of the city. The increase in manganese was very slight, and is derived from the sewage treatment plant at Gold Bar. Manganese occasionally exceeded the Alberta Surface Water Quality Objective; however, there is little concern with the levels measured in the study.

Nickel also increased slightly downstream of the city, especially on the right side of the river. The source of this increase is industrial inputs from the Fort Saskatchewan area. There is no Alberta Surface Water Quality Objective for nickel, because of its very low toxicity.

Lead showed a small but definite increase in the Edmonton area. The most likely source of increased lead in the river is the burning of leaded motor fuels, and subsequent wash-off from city streets during snowmelt and rainstorms. Lead values exceeded the Alberta Surface Water Quality Objective of 0.05 milligrams per litre in seven of 317 samples collected at several locations within the metropolitan area. No exceedances were detected upstream or downstream of the Edmonton-Fort Saskatchewan



portion of the study section. The fate of lead entering the river in this area is not known. The possibility of accumulation in sediments or in aquatic organisms must be considered, although there is no evidence for this at the present time.

Zinc concentrations did not show a clear longitudinal pattern, although the highest values tended to occur at sites downstream of the city. The largest sources of zinc are the Gold Bar sewage treatment plant effluent and several industrial effluents in the Fort Saskatchewan area. Levels of zinc were below the

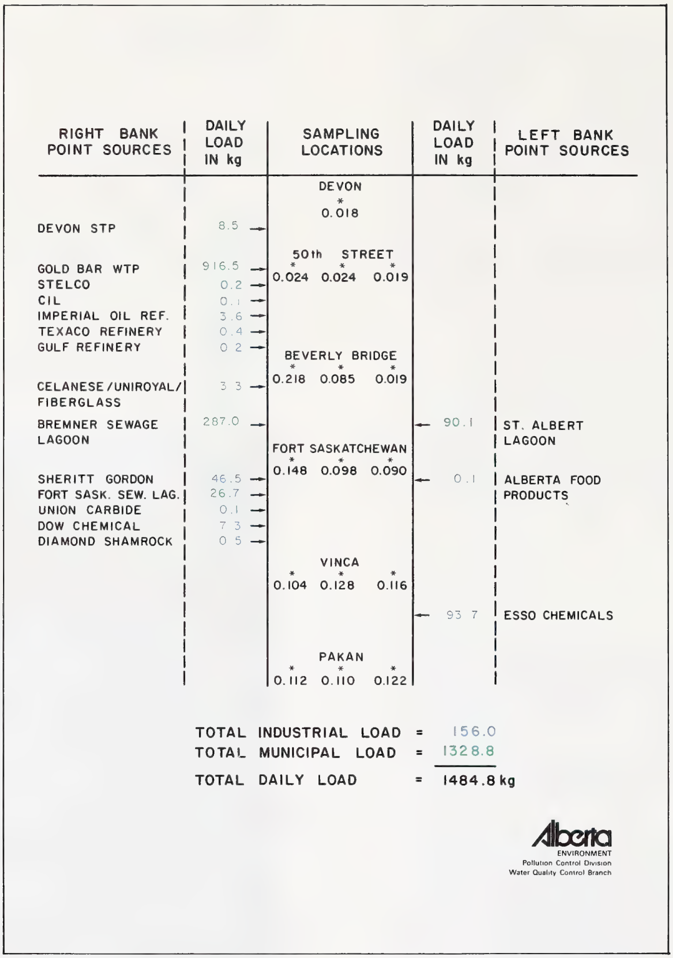


FIGURE 4 Diagram of phosphorus loadings (kilograms per day) to the North Saskatchewan River and median concentrations (milligrams per litre) of total phosphorus in the river 1983 -1984.

Alberta Surface Water Quality objectives in 478 of 500 samples; the few exceedences showed little relationship to point sources, although they occurred at all sampling locations within the city and downstream.

Organic Compounds

Organic compounds are complex or simple molecules containing carbon. Natural organic chemicals are derived from soils, the breakdown of plants and animals, and weathering of bedrock. Such organic substances can be expected to occur naturally in the aquatic environment. In addition to natural inputs of organics, human activities within the river basin contribute small quantities of synthetic and natural organic compounds.

No detectable levels of chlorinated pesticides, chlorinated herbicides, organophosphorus or organonitrogen compounds, or PCBs were found in the North Saskatchewan River samples in the study. The occurrence of acid and base/neutral fractions and purgeable priority pollutants near or below the analytic detection

limit suggests that these compounds are of very low risk to water users. These occurrences showed no apparent relationship to point sources. No surface water quality standards have yet been set for priority pollutant compounds.

The concentration of total phenolic compounds in North Saskatchewan River samples only rarely exceeded the Alberta objective level. Of the few high values, most were in unmixed sections of the North Saskatchewan River below point sources. Some phenolic compounds are of natural origin, but most are derived from municipal and industrial point sources in the Edmonton region. At the levels detected, it is likely that the greatest impact of phenolics would be one of imparting taste and odor to drinking water.

Nutrients

Substances that are required for the growth of plants and animals are called nutrients. In surface waters, phosphorus and nitrogen are often in low supply relative to the needs of aquatic plants, and plant growth is limited. If the nutrient supply should increase, as for example when sewage effluent enters a river, excessive plant growth may occur. Such excessive growth can in turn reduce dissolved oxygen levels at night in summer or during the winter.

Total phosphorus concentrations in the North Saskatchewan River were considerably higher downstream of the city than upstream. The largest sources were the Gold Bar and Bremner sewage treatment plants, which discharged to the right (south) side of the river. These large inputs are reflected in high phosphorus values in samples from the right bank sites from 50th Street Footbridge to Vinca Bridge. Concentrations in samples from the centre of the river increased gradually in a downstream direction, and samples from the left side were low as far downstream as Ft. Saskatchewan (Figure 4.) Concentrations at Pakan were similar in left, centre and right samples, but were somewhat lower than could be accounted for when all the inputs along the river are added. This deficit implies a loss or uptake of phosphorus, probably by the large aquatic plants or algae growing on the river bottom.

The Alberta Surface Water Quality Objective for total phosphorus was frequently exceeded during the sampling program. The objective was exceeded in over 90% of the samples from Pakan. Even at the two sites upstream of the city, the Alberta objective was exceeded in about 20% of the samples, perhaps indicating that the Alberta objective level is inappropriate for this particular river. The high values from upstream sites occurred during high flows when the river was silty; the phosphorus associated with these sediment particles is of a form that is less usable by plants than that derived from sewage.

The spatial pattern for total nitrogen was similar to that for total phosphorus: large inputs of nitrogen from the sewage treatment plants resulted in high concentrations on the right side of the river which gradually mixed in a downstream direction.

The Alberta Surface Water Quality Objective for nitrogren was exceeded mainly at right-bank sites near point-source discharges and at the furthest locations downstream. At Pakan, the objective was exceeded in approximately 24% of the samples collected in 1983. Under favorable environmental conditions, high concentrations of nitrogen and phosphorus may result in nuisance plant growth.

Chlorophyll a

The quantity of the photosynthetic pigment chlorophyll **a** in a water sample is a measure of the amount, or biomass, of algae in the water. The free-floating algae in a river orginate either from the bottom or from quiet areas or backwaters along the river's edge. The algae that grow attached to rocks were also measured during the study by extracting chlorophyll **a** from rock scrapings.

Chlorophyll **a** in samples for both free-floating and attached algae increased significantly in the North Saskatchewan River below major nutrient sources such as the Gold Bar Wastewater Treatment Plant. Differences between upstream and downstream chlorophyll **a** were

accentuated during the summer low-flow period when light and temperature were optimal for growth. At this time, low nutrient levels probably limited growth upstream of the city.

No surface water quality guidelines have been set for chlorophyll a. The concentrations for free-floating and attached algae were generally low to moderate, and were therefore not a cause for concern. Under conditions of reduced scouring and clear water, however, a large biomass could develop which may result in reduced oxygen overnight in the river in midsummer.

Carbon

Carbon is a major constituent of the aquatic environment. Inorganic carbon, of which bicarbonate and carbon dioxide are examples, showed no seasonal or longitudinal patterns in samples from the study section of the North Saskatchewan River.

Organic carbon occurs within compounds dissolved in the water or in cells or other particles from living and dead organisms. The highest total organic carbon values tended to occur when river flows were highest. The organic carbon associated with particles was related mainly to surface runoff, much of which entered the river upstream of the study area. The dissolved fraction was clearly associated with municipal and industrial discharges and with tributary streams.

There is no Alberta Surface Water Quality Objective for organic carbon. The increase in organic carbon downstream of the city indicates enrichment which may lead to oxygen depletion as bacteria consume and break down organic compounds.

Bacteria

Bacteria are used to indicate the recreational safety of water. It is generally not possible to isolate disease-causing bacteria directly from recreational waters. Instead, an easily-measured group of bacteria known as coliforms are used as indicators of possible fecal contamination.

If large numbers of indicator bacteria are

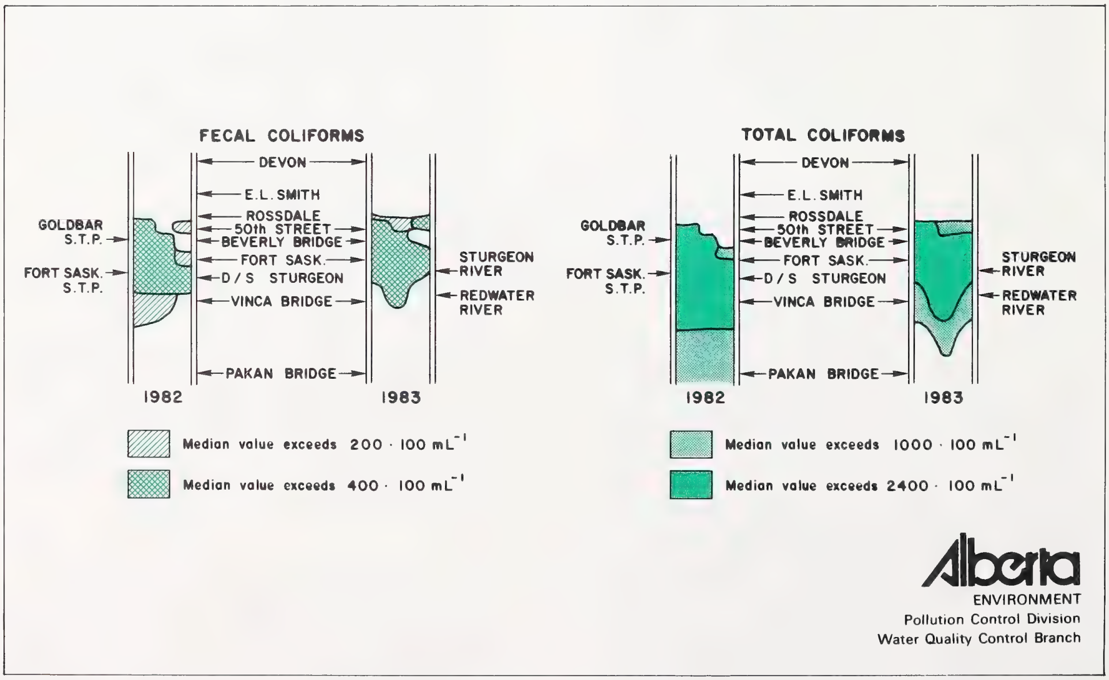


FIGURE 5 **Diagram of fecal and total coliform bacteria in the North Saskatchewan River study area.**

present, pathogenic bacteria may also be present. However, coliform bacteria occur in the intestinal tract of all warm-blooded species including humans, so relatively high numbers of fecal or total coliforms may occur even when the water is free of human pathogens.

Counts of total and fecal coliform bacteria were low in samples collected from locations upstream of the city. All samples met the Alberta Surface Water Quality Objective for direct contact recreation.

Within and below the city, however, bacterial counts were very high (see Figure 5). Counts in all samples collected immediately downstream of the Gold Bar Wastewater Treatment Plant effluent exceeded the Alberta objective level. Coliform counts tended to remain high or even increase as additional sewage effluents entered the river between Gold Bar and Fort Saskatchewan. Because of mixing in the river and natural die-off of bacteria, total numbers tended to decline by Pakan. This die-off occurred more rapidly in midsummer when the water temperature was high, so counts at Pakan were similar to those at Devon at that time. However, when the water was cool, counts at Pakan often exceeded the Alberta objective level for direct contact recreation.

The Alberta objectives for indicator bacteria are based on the assumption that health risks to swimmers or other people who contact the water directly are unacceptable when bacterial counts exceed the specified levels. Therefore, the results of the 1982-83 study suggest that swimming in the river may be safely done at Devon or other upstream areas, and at Pakan or further downstream during the warmest months. The presence of indicator bacteria in the river downstream of the city has no effect on drinking water supplies, because both water supply intakes are upstream of the zone of impact, and because drinking water is disinfected.

Biochemical Oxygen Demand

Surface waters contain various quantities of organic matter in both dissolved and particulate forms. The organic load carried by a river may be increased by the addition of municipal and industrial waste effluents. The organic matter is gradually broken down by bacteria, and this process consumes oxygen. The biochemical oxygen demand (BOD) of water may be measured in a laboratory. This test is used to assess the potential oxygen requirements of waste discharges entering receiving waters, although the actual oxygen demand might be quite different than that measured in a laboratory.

The BOD in the North Saskatchewan River approximately doubled between sampling locations upstream and downstream of the city. Samples from the left side of the river remained low through the city but gradually increased to maximum concentrations at Vinca and Pakan. BOD in samples from the right side of the river was high at Beverly Bridge, downstream of the Gold Bar Wastewater Treatment Plant. During dry weather the greatest load was derived from sewage effluent, but during a high flow, the tributary streams contributed the greatest load of BOD.

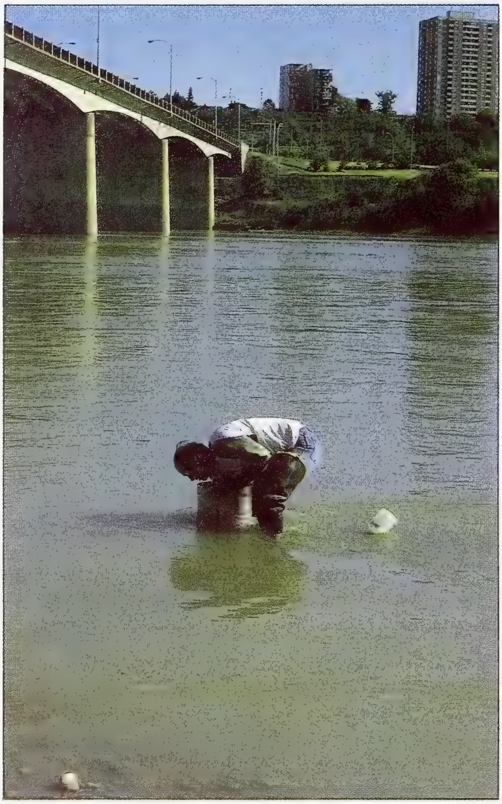
The Alberta Surface Water Quality Objectives state that BOD must not exceed a level which would create a dissolved oxygen content in the river of less than 5 milligrams per litre. Dissolved oxygen measured during the study was never less than 5 milligrams per litre, indicating little impact of BOD.

Other standards suggest that BOD values under 4 milligrams per litre are indicative of clean water. In this study, more than 95% of all BOD values were less than 4 milligrams per litre. The impact of organic loads on the river dissolved oxygen is generally low.

Zoobenthos

The animals that live on, under and among the rocks and sediments of the river bottom are referred to as the zoobenthos. Most of these animals are immature stages of insects, such as mayflies, stoneflies, caddisflies, and midges, but the zoobenthos also include worms, snails or other invertebrate types. The zoobenthos have inherent qualities that make them useful in assessing water quality

in rivers. They have a relatively long life cycle, perhaps as long as two or three years in some species. Many of them are sensitive to pollution, so their presence or absence can be used as an indicator of the condition of the water. Their limited ability to move around means that they cannot rapidly migrate out of an impacted area.



Collecting zoobenthic organisms.

Zoobenthic organisms were collected in spring, summer and fall of 1982 at eleven locations from Devon to Pakan at both left-bank and right-bank sites. An analysis of this large data set led to the identification of three major zones of water quality along the study section (See Figure 6).

Zone I was an unimpacted section. It included sites that were upstream of major point source effluents, including the two sites upstream of the city and several sites within the city. depending on the season. In this zone, bottom-dwelling animals were virtually unimpacted; the species found there were indicative of river water of high quality. Mayflies, stoneflies and caddisflies, considered to be "clean water" types, were abundant.

Zone II was impacted by point-source discharges within and below the city. Total numbers of organisms were higher than in Zone I. The numbers of pollution-tolerant organisms increased, so that the percentage of clean-water types decreased.

Zone III was a section downstream of Zone II showing some recovery. Total numbers of organisms were still much higher than in Zone I, but the percentage of clean-water species increased.

Municipal discharges, including storm and combined sewers, were largely responsible for the existence of zones of different water quality in the North Saskatchewan River between Devon and Pakan. Species tolerant of large organic loads responded to these point sources by increasing in numbers. It was also determined that this increase was greater below combined sanitary/storm sewers than below sewers discharging only storm water. The greatest impact was seen below the discharge from the Gold Bar Wastewater Treatment Plant.

Impacts of industrial discharges were masked by the enrichment effects of the Gold Bar discharge. There appeared to be no overall toxic effect within the study section, as demonstrated by the zoobenthos.

The length of the zone of impact depends on river flow and water temperature, as well as the quality and volume of effluent. The impact zone tends to be shorter in the fall than in the spring, because the water is warmer, and the breakdown of organic matter occurs rapidly. Additionally, the early summer peak flow scours the river bottom, cleaning it of organic debris.

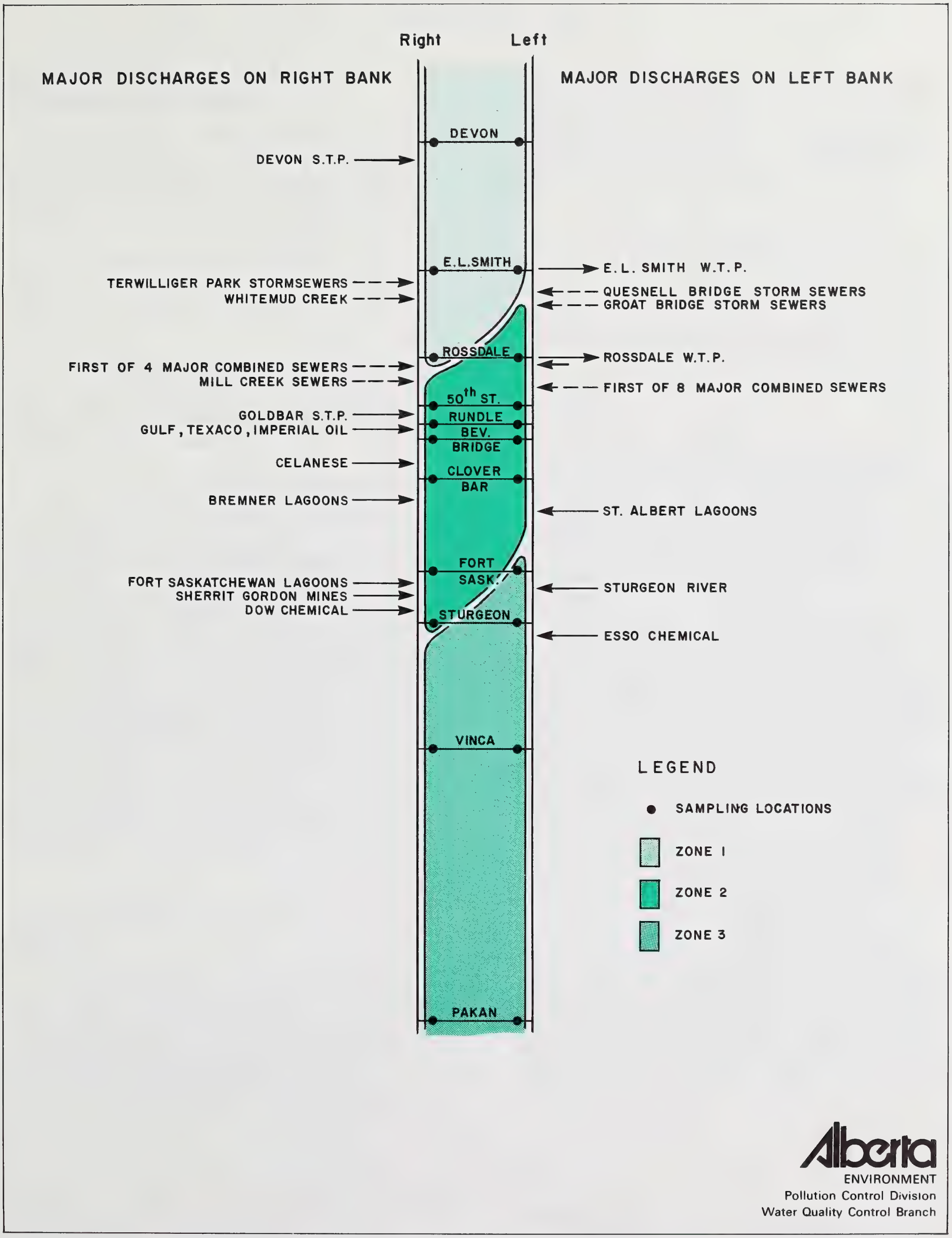


FIGURE 6 **Diagram of zones of impact on zoobenthic organisms in the North Saskatchewan River study area.**

CONCLUSIONS

How has water quality in the North Saskatchewan River changed?

During the late 1960s and early 1970s, public attention was focused on environmental quality, and people became concerned about the condition of the North Saskatchewan River. A survey of public perception of water quality in the river was conducted in 1972.[1] Of 385 respondents from all over the City of Edmonton, 60% believed that the water leaving the city was very polluted.

Public perception has not changed since then. If anything, media attention has probably increased the number of people who believe the river to be polluted.

However, water quality in the North Saskatchewan River has improved considerably over the past thirty or more years. For example, during the winter in the 1950s, oxygen was often at levels below the present Alberta Surface Water Quality Objective of 5 milligrams per litre. At times it was zero at the Saskatchewan border. The water appeared "dirty" with bits of garbage and visible grease, and it had sewage-like odors.[2] Since then, all municipal and industrial wastewaters are treated, and winter flow from the reservoirs is higher. Water quality in the river has improved to the extent that winter oxygen is maintained at the Alberta objective level as far downstream as the border with Saskatchewan.

How does water quality vary over time and distance?

Water quality in the North Saskatchewan River varies naturally over the seasons, especially in response to changing flow. High flows in the spring and early summer are a result of local mountain runoff. At this time, soil particles and organic debris are carried into the river, and it appears muddy or silty with suspended solids. Substances that are naturally associated with suspended solids, such as phosphorus, iron, aluminum, manganese and certain organic compounds, also increase.

When flow in the river declines in late summer, concentrations of these particulate substances decrease while concentrations of certain dissolved substances such as major ions increase. It is at this time, too, that algae and other aquatic plants growing on the river bottom have produced their maximum growth, in response to high temperature and high levels of light.

As winter approaches, aquatic plants die and decay, releasing stored nutrients and organic compounds. Ice cover inhibits aeration, and oxygen levels may decline somewhat. Concentrations of ammonia nitrogen and dissolved phosphorus may increase.

Superimposed on these natural occurrences in the river is the effect of municipal, industrial and stormwater discharges from the metropolitan area. These effects were determined during the study by comparing water quality upstream and downstream of the city. Substances that were higher immediately downstream included dissolved organic carbon, nitrogen, phosphorus, sodium, potassium, chloride, sulfate, nickel, manganese, lead and zinc. Additionally, biochemical oxygen demand, chlorophyll a (algae), zoobenthos, and bacteria were higher downstream than upstream in response to inputs of organic matter. In many cases, levels of these chemical and biological components declined gradually in a downstream direction. Differences from one side of the river to the other were also apparent within the city and downstream to Pakan where the river was mixed.

1 *Watson, D.J. 1972. Perception and management of water quality in the North Saskatchewan River at Edmonton, Alberta. M.Sc. Thesis, Dept. of Geography, Univ. of Alberta.*

2 *Bouthillier, P.H. 1984. A history of stream pollution assessment and control — the North Saskatchewan River 1950s to 1980s. Report to Water Quality Control Branch, Alberta Environment*

How does present water quality compare to the Alberta Surface Water Quality Objectives?

There are no Alberta objectives for many of the chemical substances measured during the study, such as the major ions, many trace organic compounds, and total organic carbon. These are considered harmless at the levels measured. There are also no objectives set for chlorophyll a and zoobenthos.

Many water quality components, namely temperature, dissolved oxygen, biochemical oxygen demand, most metals and certain organic compounds, either complied with the objectives or were undetectable in the water.

Some substances, such as phenolic compounds, ammonia-nitrogen, lead and zinc occasionally exceeded the objectives. A few constituents regularly or frequently exceeded the objectives: natural levels of iron and manganese; about 90% of samples for total phosphorus and 30% of samples for total nitrogen exceeded the objectives at Pakan; 21% to 35% of all bacterial samples exceeded the objectives at Pakan. The percentage of samples exceeding the objectives were usually higher near sewage treatment plant outfalls.

How do urban development and other impacts affect water quality?

Municipal sewage treatment plant effluents had the greatest impact on the study section of the North Saskatchewan River. These effluents are rich in phosphorus, nitrogen, organic material and indicator bacteria. As a result, the biomass of free-floating and attached algae increased between sites upstream and downstream of the city. The biomass of pollution-tolerant zoobenthos was also higher downstream. Indicator bacteria were abundant in samples as far downstream as Pakan, except in August.

How are uses of the river affected by the impact of urban development?

The major uses of the North Saskatchewan River in the study section are for municipal water supply, for cooling in power plants, and for the assimilation of waste loads. Minor uses are for swimming, boating, fishing, stockwatering and the irrigation of crops. As with many multiple-use resources, there are conflicts among these uses of the river.

For example, high numbers of coliform bacteria downstream of the Edmonton urban area limit the use of river water for swimming, livestock watering and irrigation of vegetable crops. Although the river's use as a municipal water supply also would be limited by bacteria immediately downstream, there are no such withdrawals at the present time. Although a very large set of data was collected during the study, many concerns, such as the impact from the urban area on fish, could not be thoroughly addressed, nor could the effects of possible interactions among the various substances in the water. These issues are extremely complex, and require further study.